Wind Integration and Transmission: Challenges and Solutions

November 3, 2009

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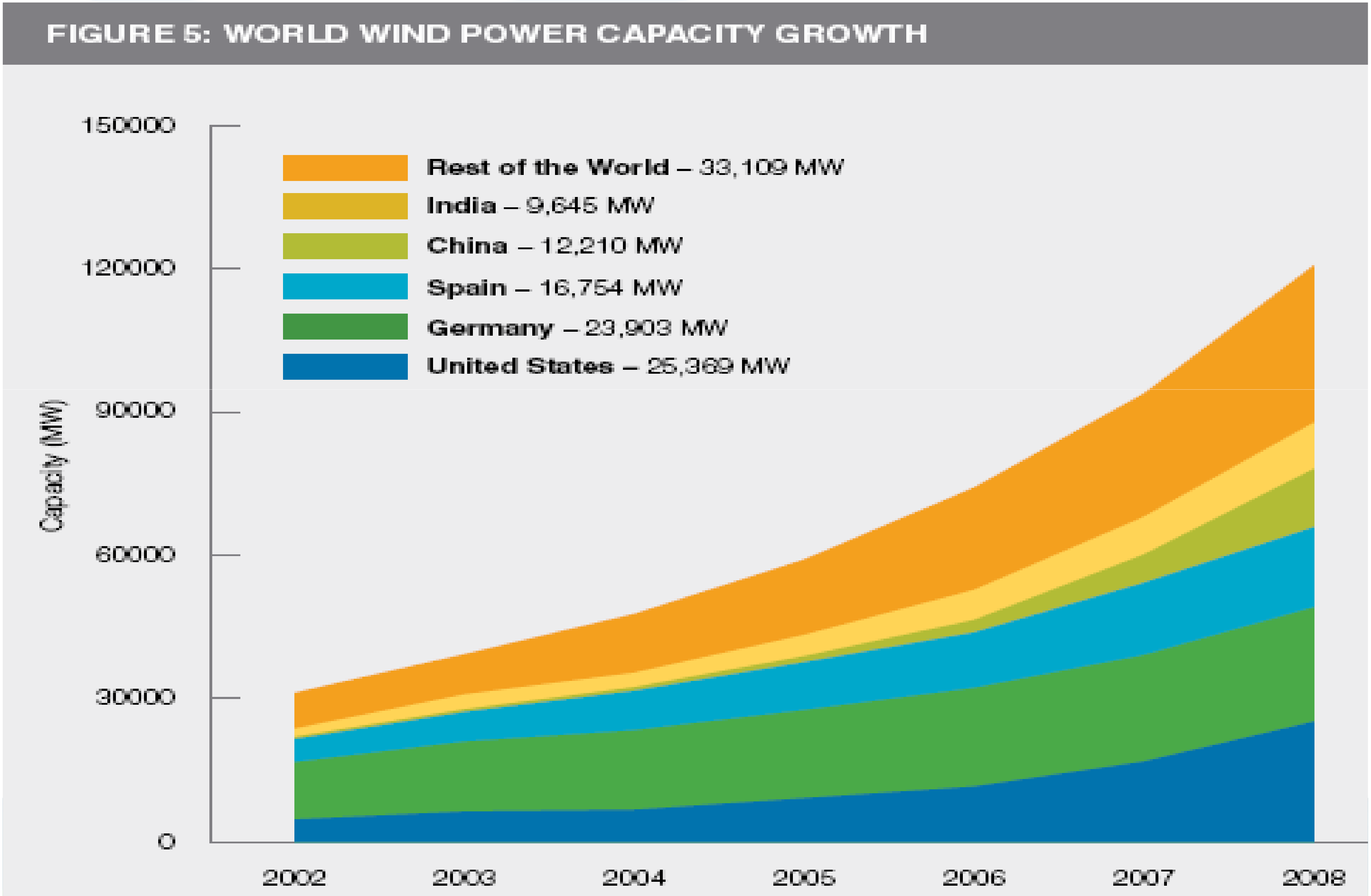
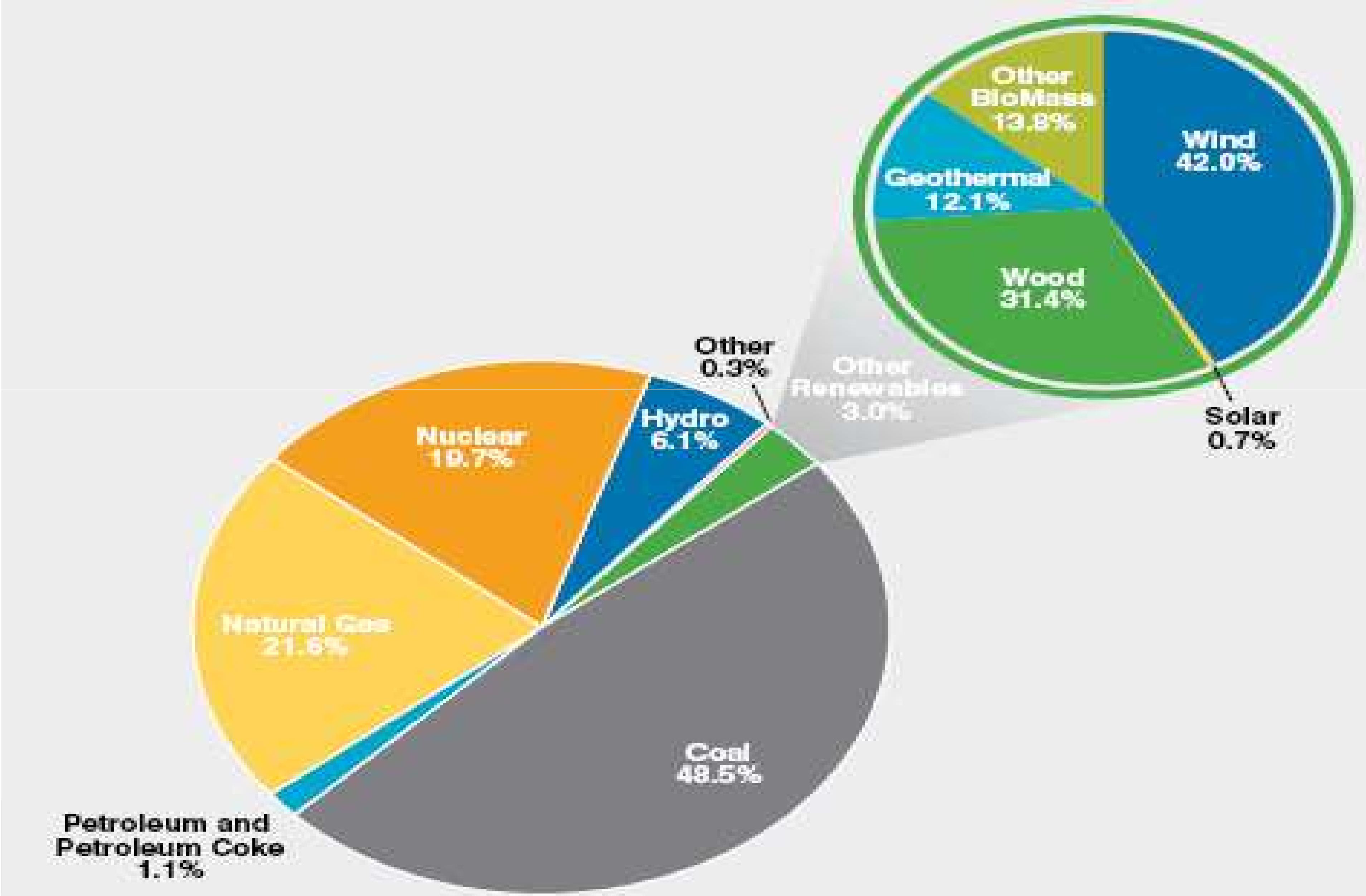
Outline

- Overview of recent wind growth
- Factors driving growth
- Transmission and grid integration issues

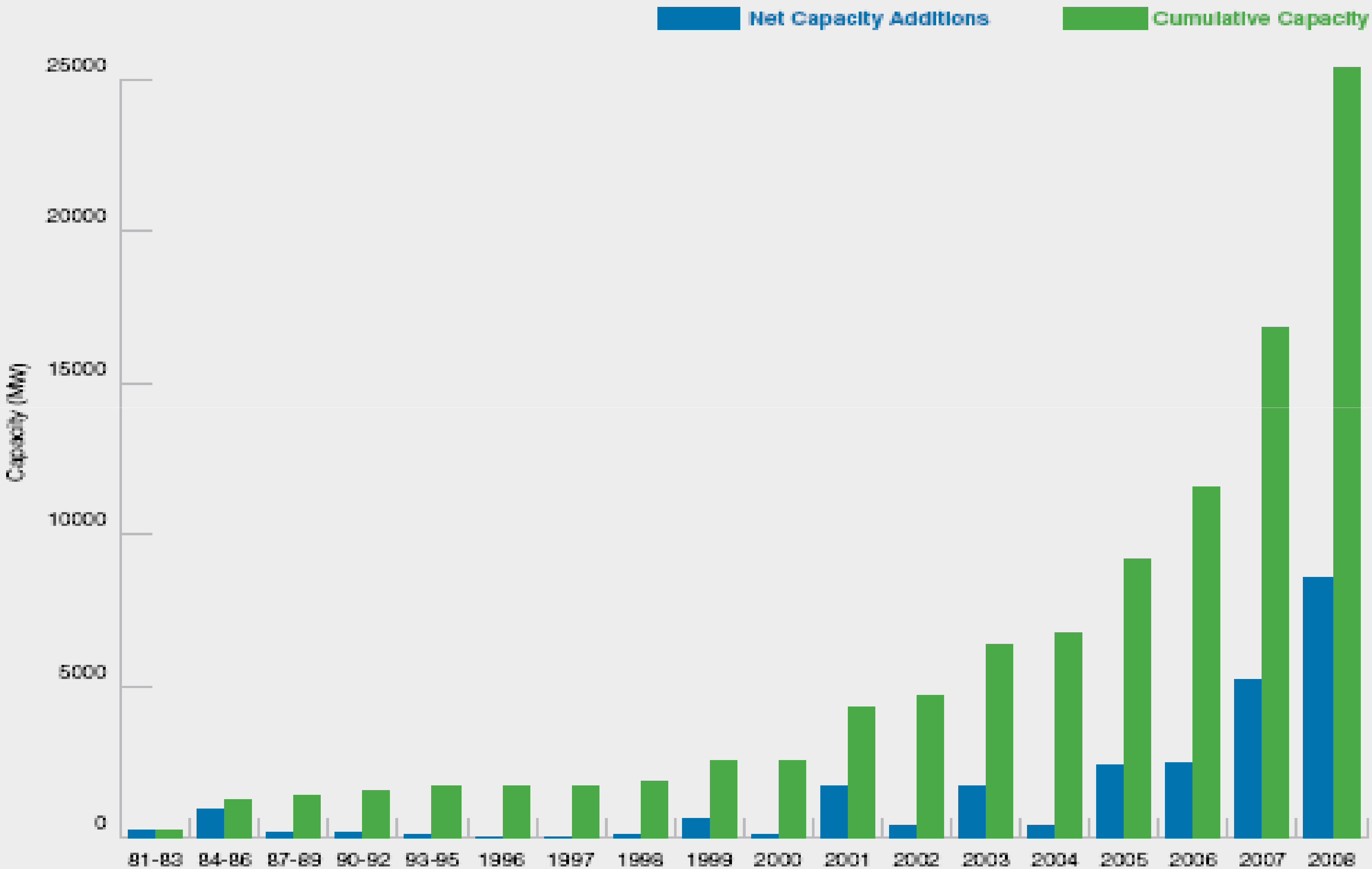
Global Wind Growth



Current U.S. Generation Mix

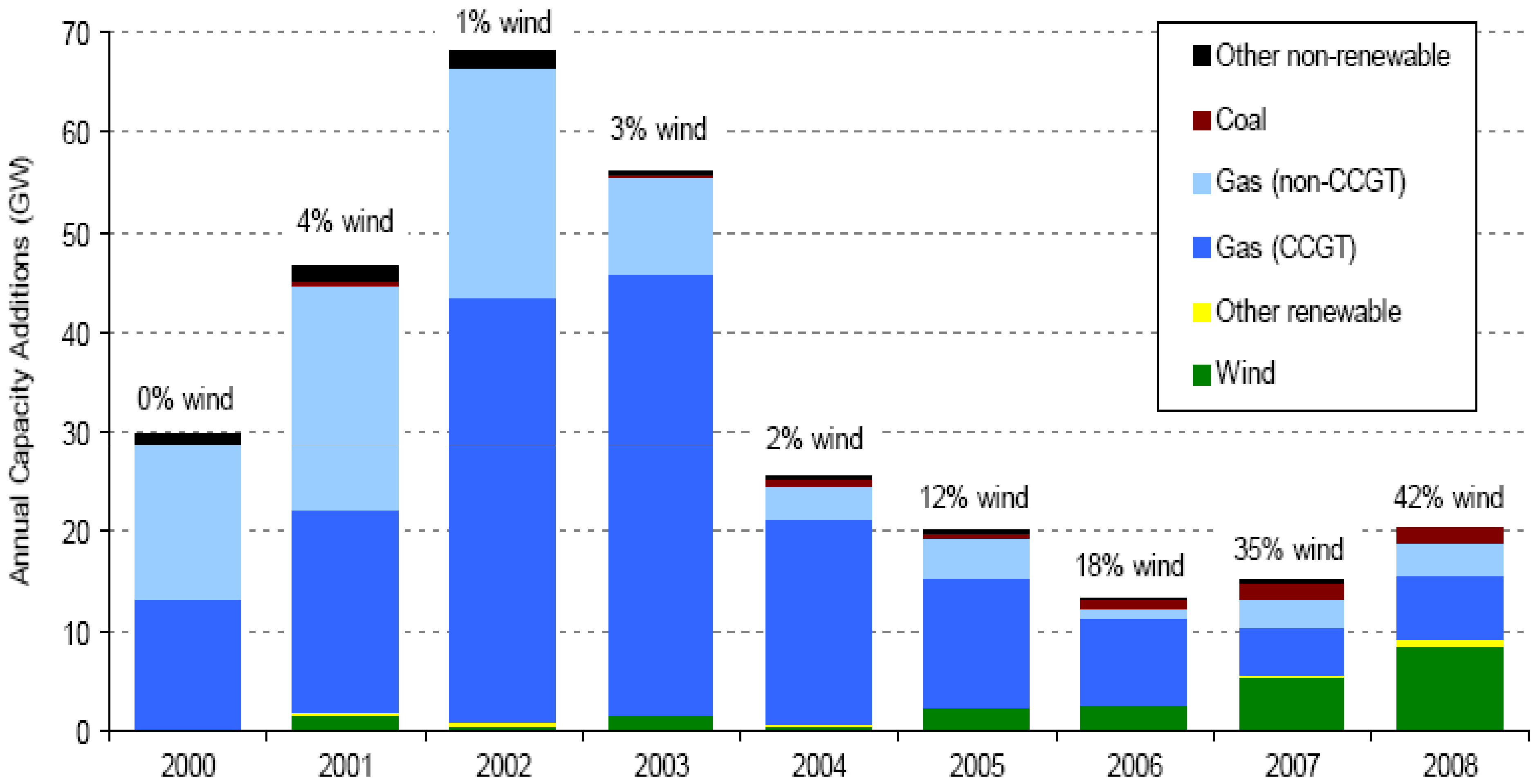


U.S. Wind Growth



Wind capacity additions in 2008 were 8558 MW. 12.5 MW of wind power were decommissioned.

U.S. Wind Growth



Source: EIA, Ventyx, AWEA, IREC, Berkeley Lab

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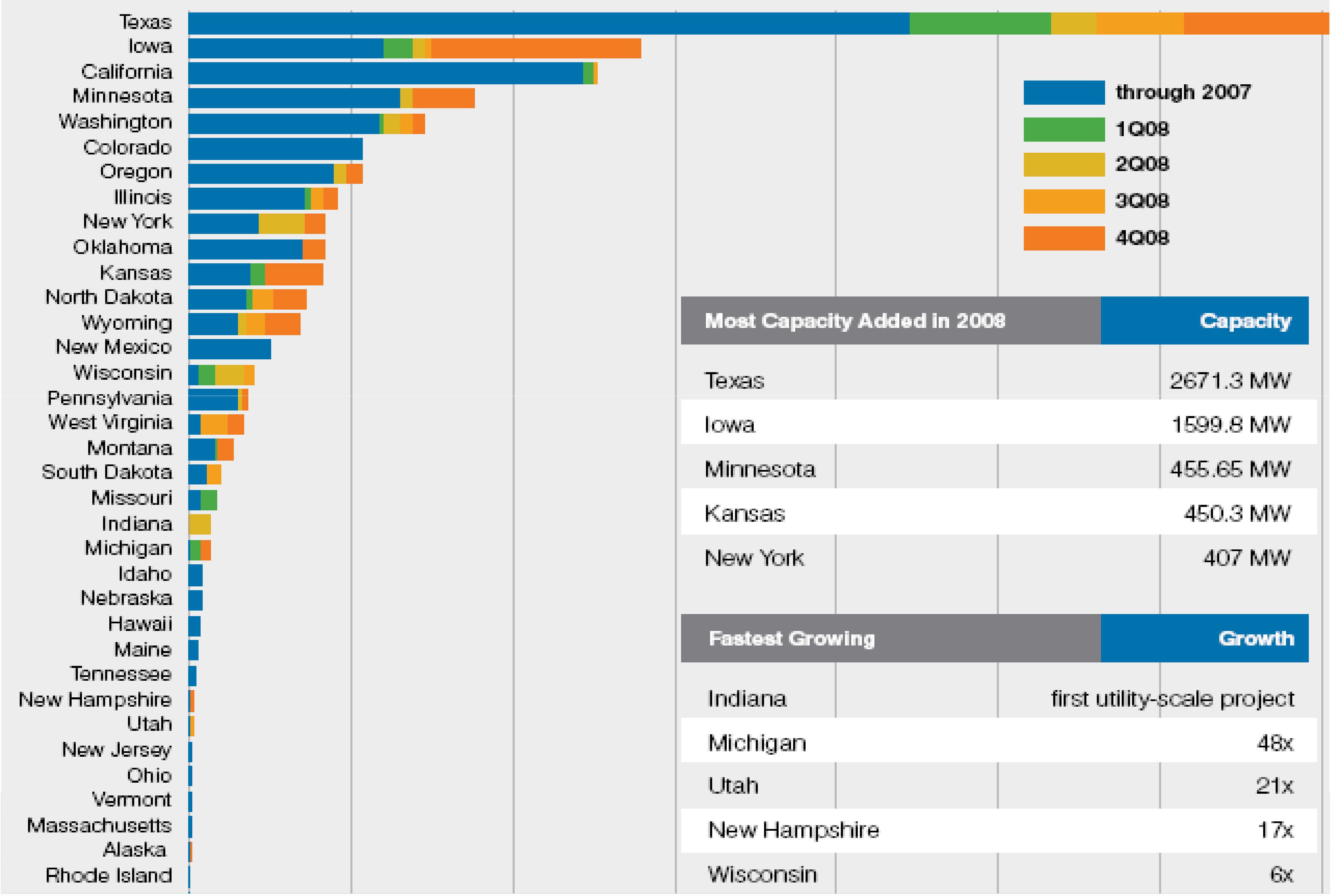
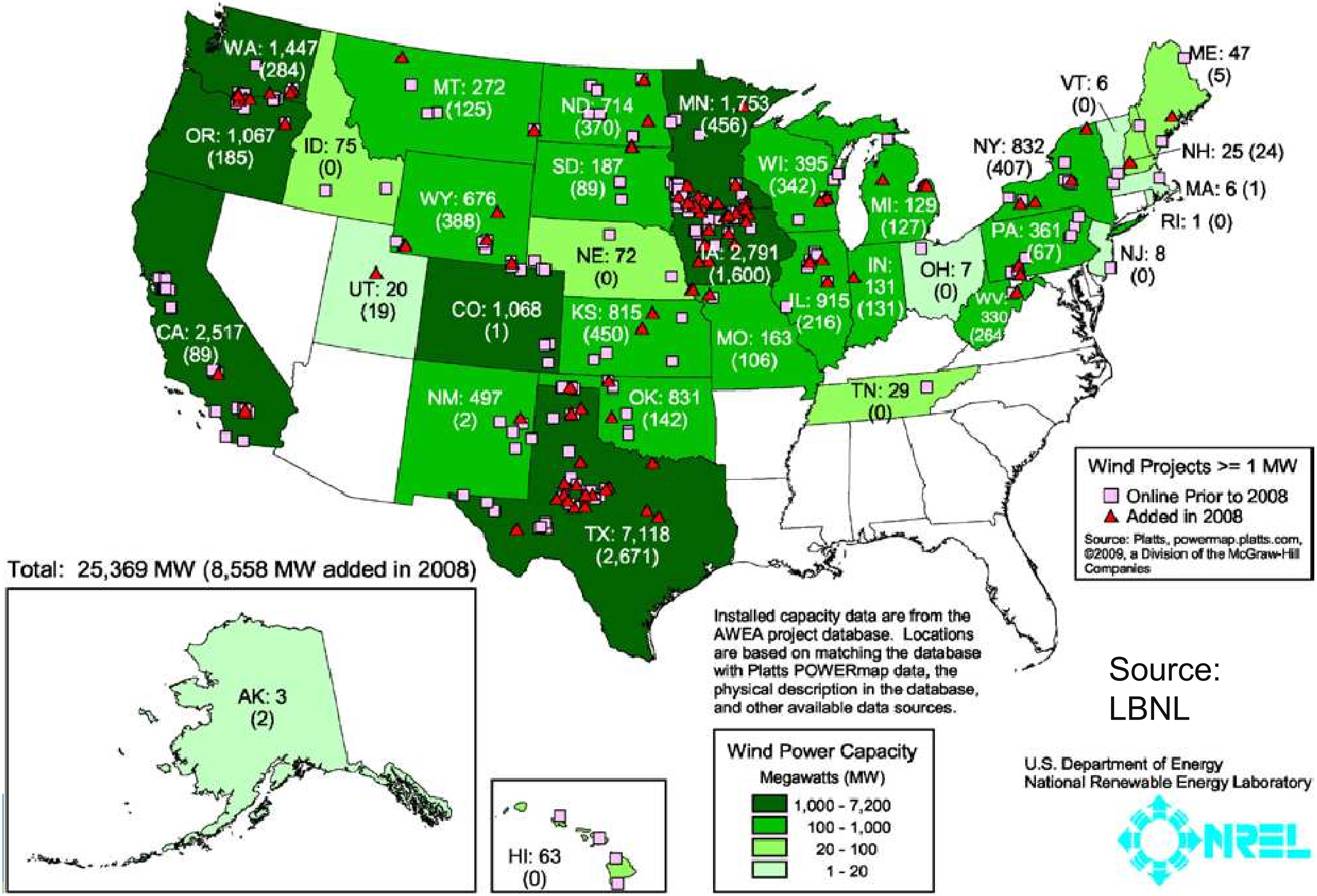
U.S. Wind Growth, by State



Most Capacity Added in 2008	Capacity
Texas	2671.3 MW
Iowa	1599.8 MW
Minnesota	455.65 MW
Kansas	450.3 MW
New York	407 MW

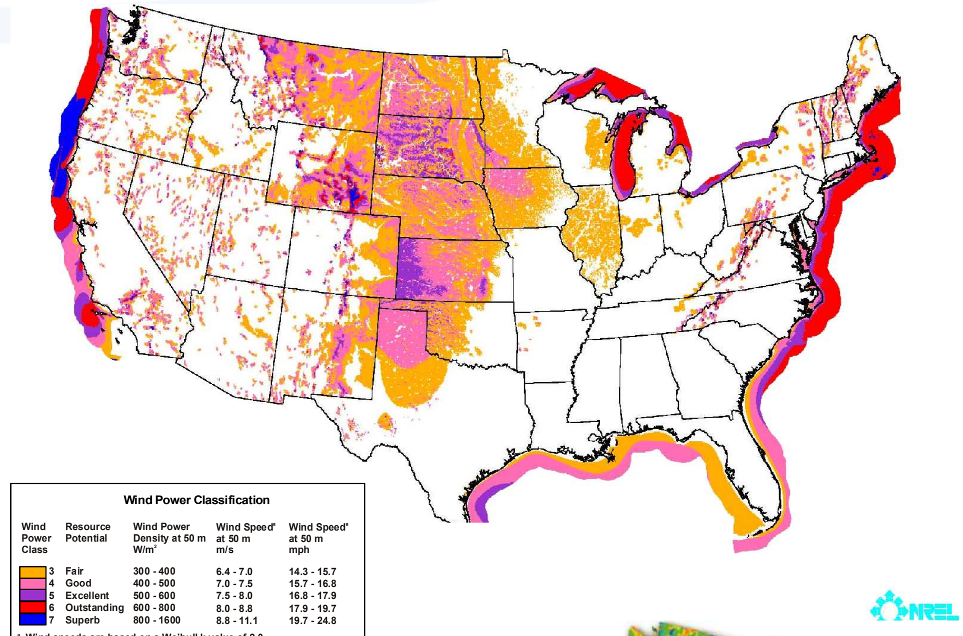
Fastest Growing	Growth
Indiana	first utility-scale project
Michigan	48x
Utah	21x
New Hampshire	17x
Wisconsin	6x

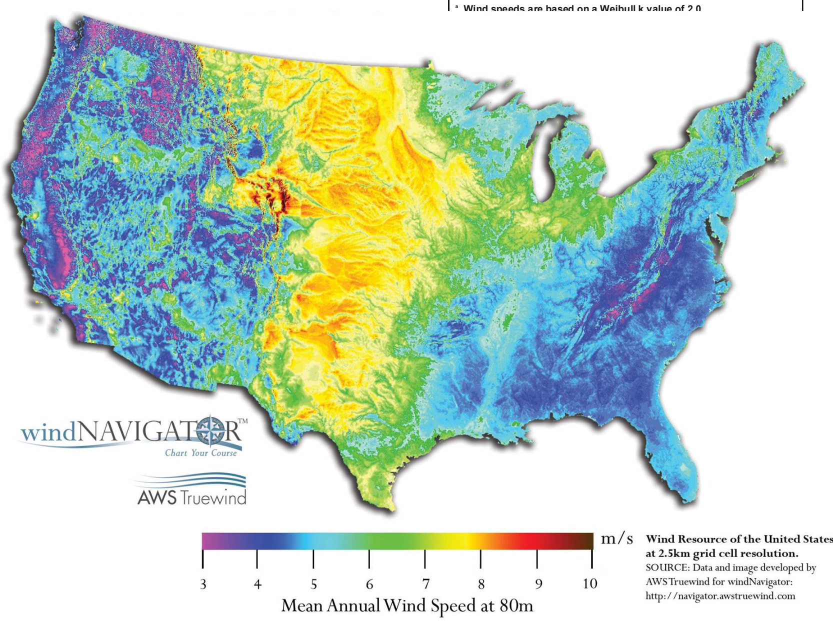
U.S. Installed Wind, by State

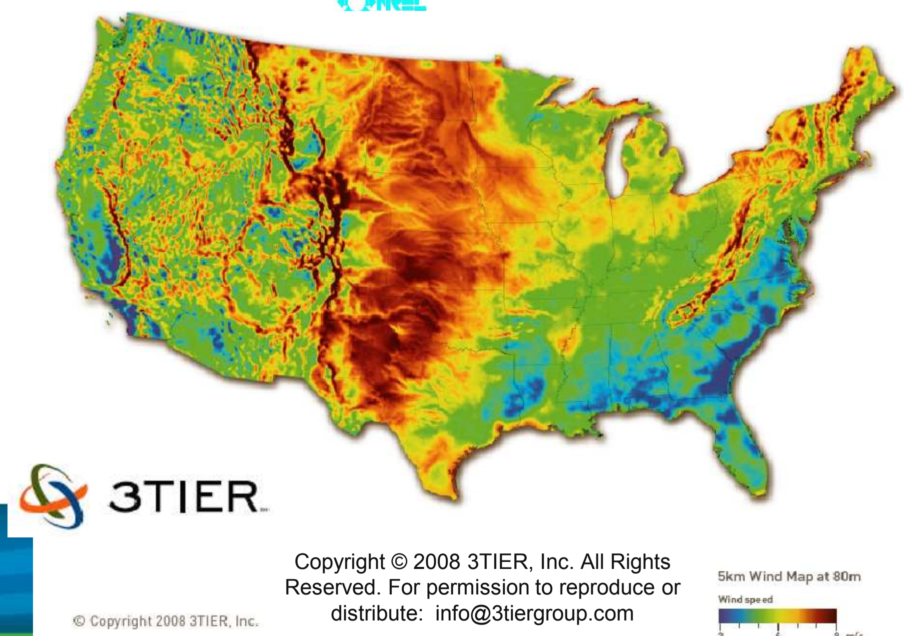


Source: LBNL

U.S. Wind Resource Maps

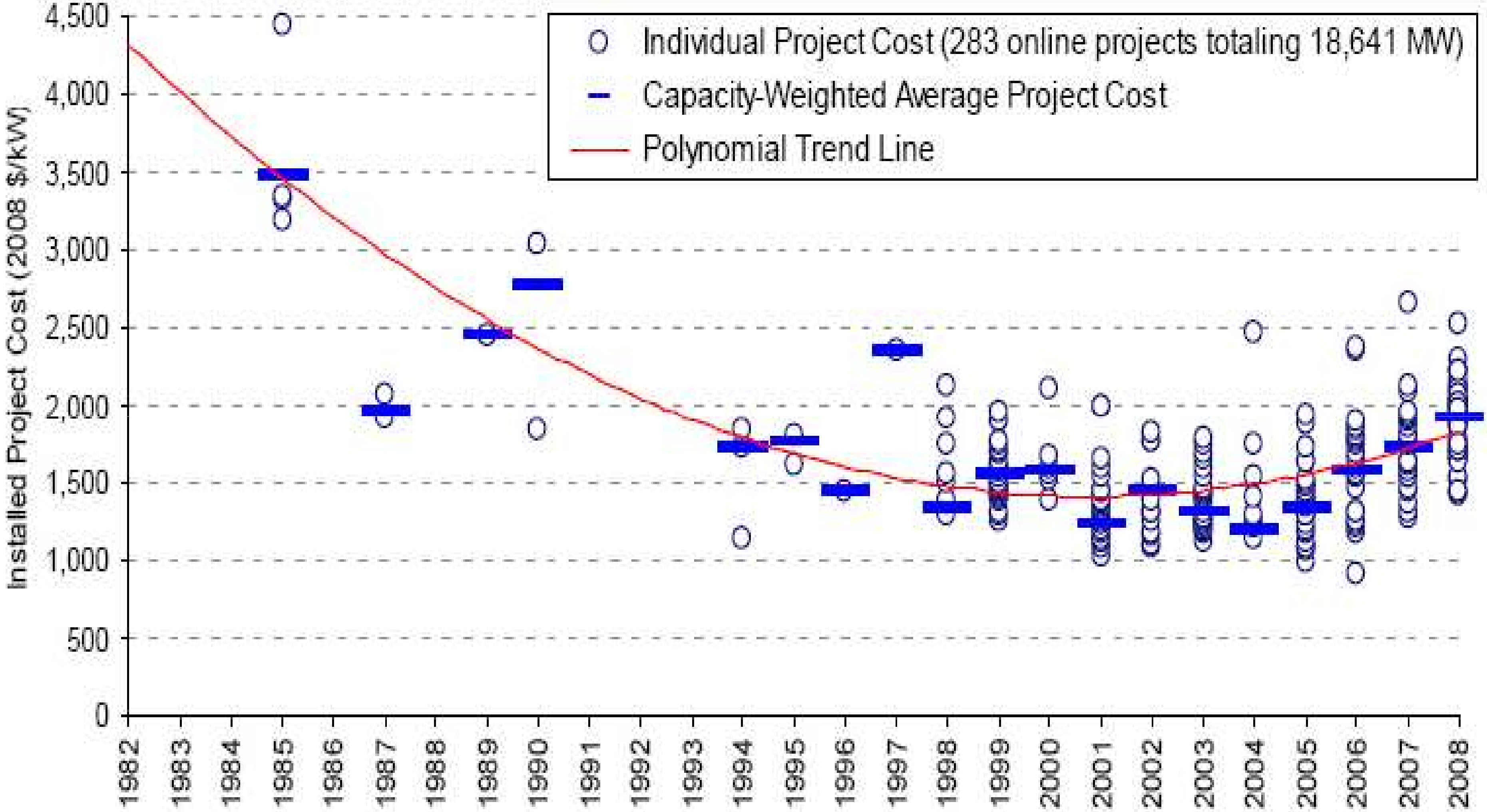






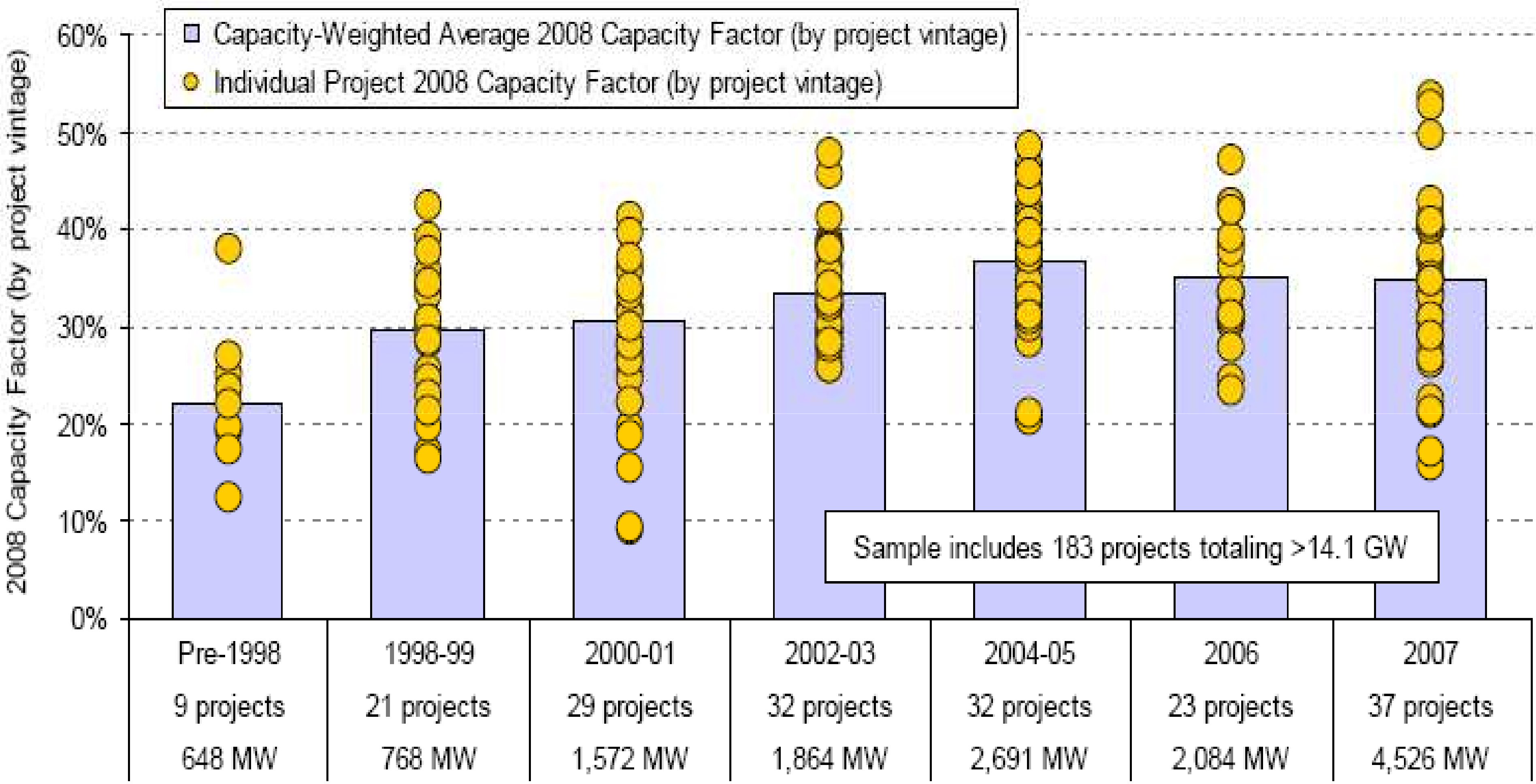
Factors Driving Wind Growth

Wind Project Capital Costs Over Time



Source: Berkeley Lab database (some data points suppressed to protect confidentiality)

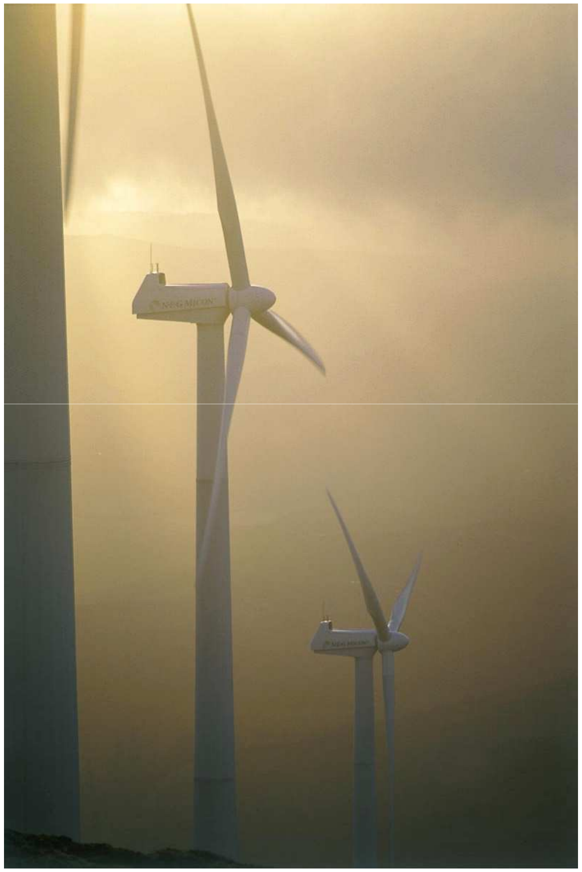
Project Capacity Factors Generally Improving



Source: Berkeley Lab database

Benefits of Wind Power
Environmental

- No air pollution (SO_2,NOx,Hg)
- No water pollution
- No global warming impacts
- No fuel = no mining / drilling
- No water use

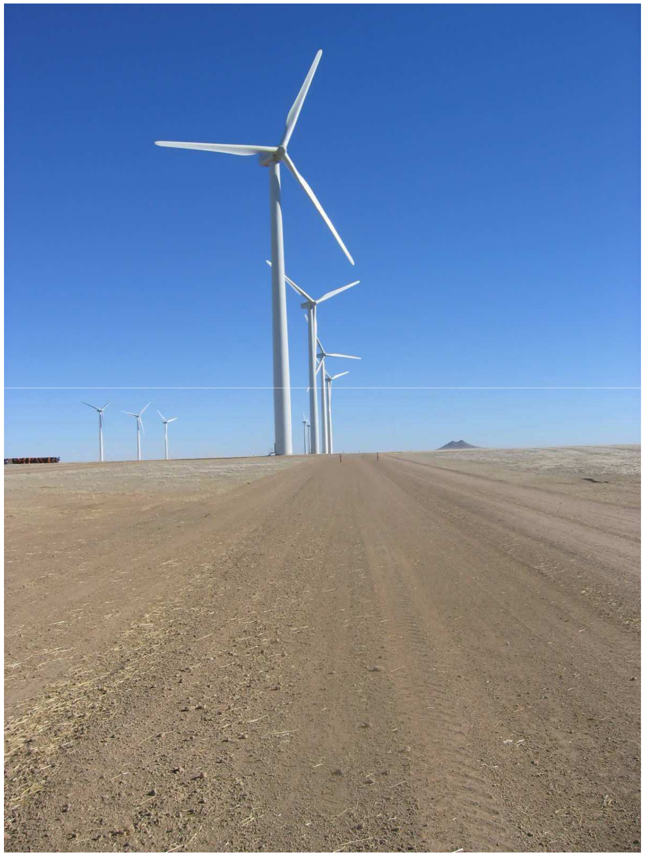


Benefits of Wind Power

Economic Development

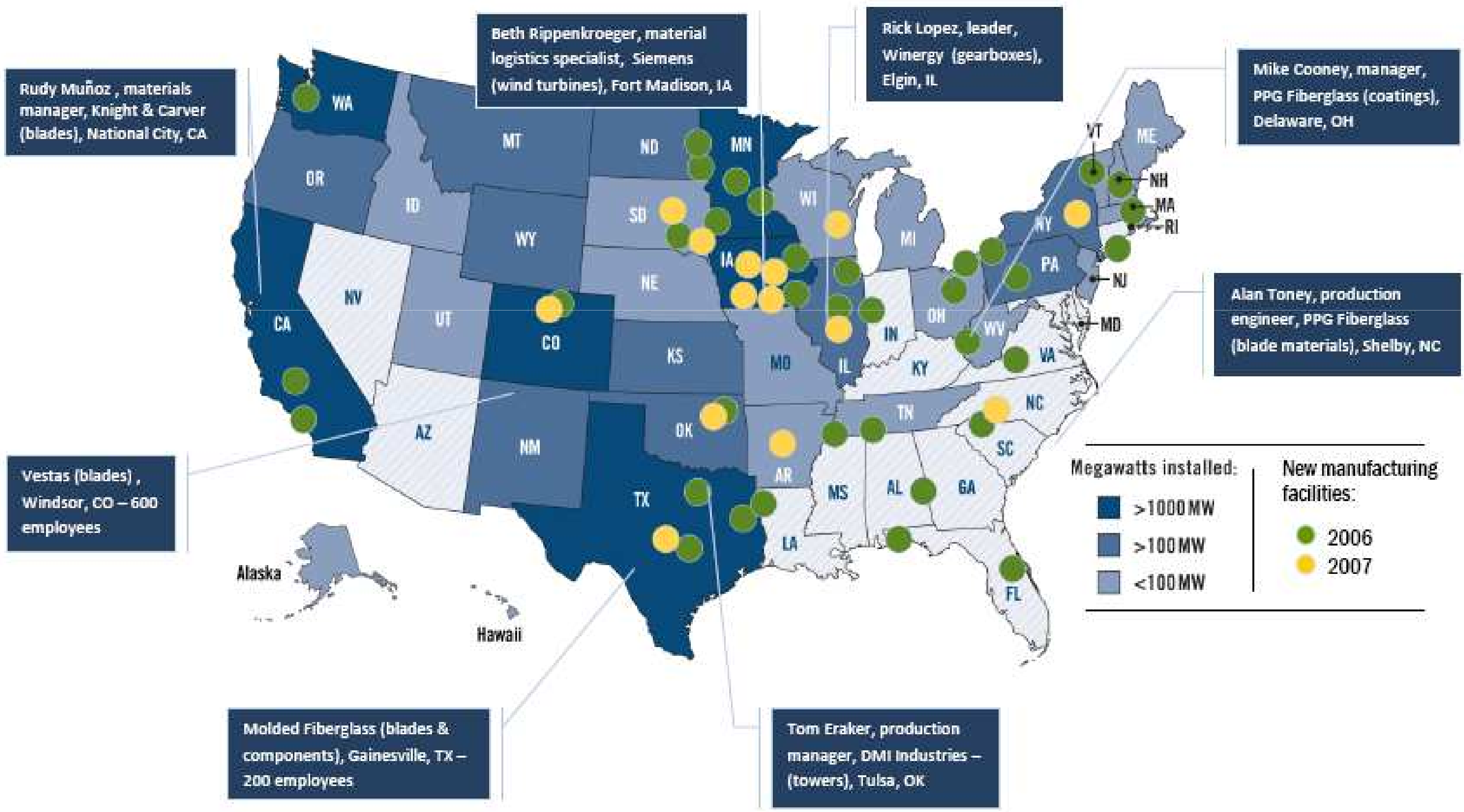
Case Study: 162MW Colorado Green Project near Lamar, Colorado

- $3,000-$6,000 per 1.5-MW turbine in revenue to farmers
- Up to 400 construction jobs and ongoing 15-20 O&M jobs
- Sales tax revenues jumped 62% in one year, from $95,000 to $154,450. The tax base has increased by 29%.



Source: U.S. DOE report, “From Snack Bars to Rebar” by Craig Cox

Benefits of Wind Power
Green Jobs



Benefits of Wind Power

Cost Stability

- Known pricing offers hedge against fuel price volatility risk
- Utilities and merchant plants capitalizing on hedge value
- Zero emissions electricity provides a hedge against uncertain carbon price risk
- Energy output is inflation-proof once wind project begins to operate
- Utilities starting to value this "price hedge"

Benefits of Wind Power
Fuel Diversity

- Domestic energy source
- Inexhaustible supply
- Small, dispersed design reduces supply risk
- Reduced natural gas consumption

Transmission and Integration Issues

Transmission and Integration Issues

- **Transmission:** How to build the transmission lines needed to connect wind projects and move power from region to region.
- **Wind Integration:** How to operate the power system with added variability and uncertainty.

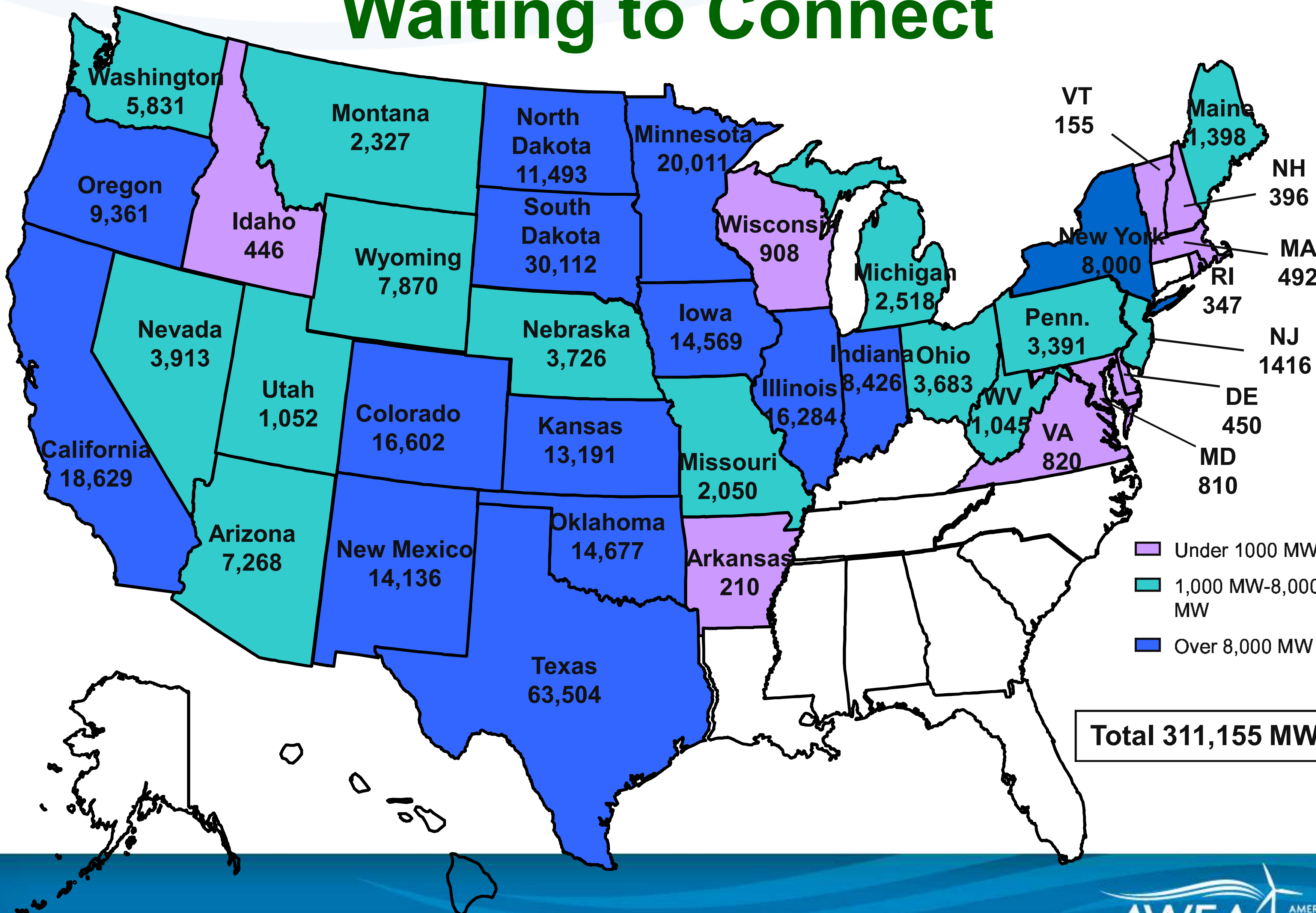
Transmission

Transmission is a Problem

- Poll of Attendees at AWEA’s WINDPOWER 2008 and 2009 Conferences: Transmission Largest Obstacle to Wind Growth

- How a lack of transmission hurts renewables:
  - Renewable projects cannot connect to the grid
  - Country’s best wind and solar resources are far from cities
  - Project output can be curtailed because of inadequate transmission
  - Cannot capture benefits of geographically diverse resources

300,000+ MW of Proposed Projects Waiting to Connect



Total 311,155 MW

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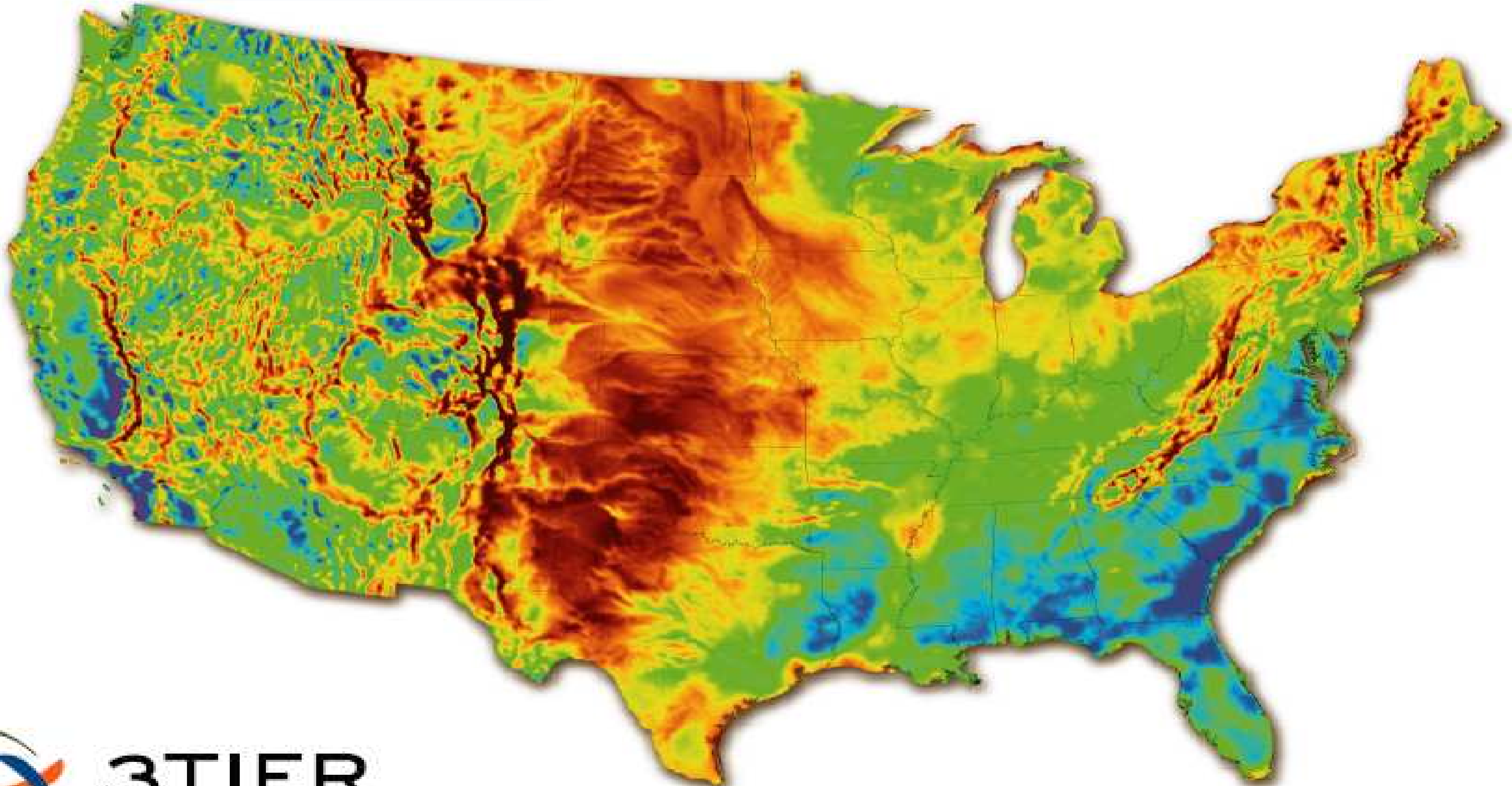
Wind Resources Distant from Demand



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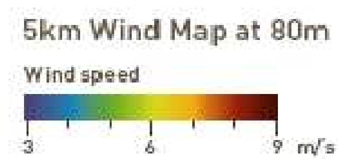
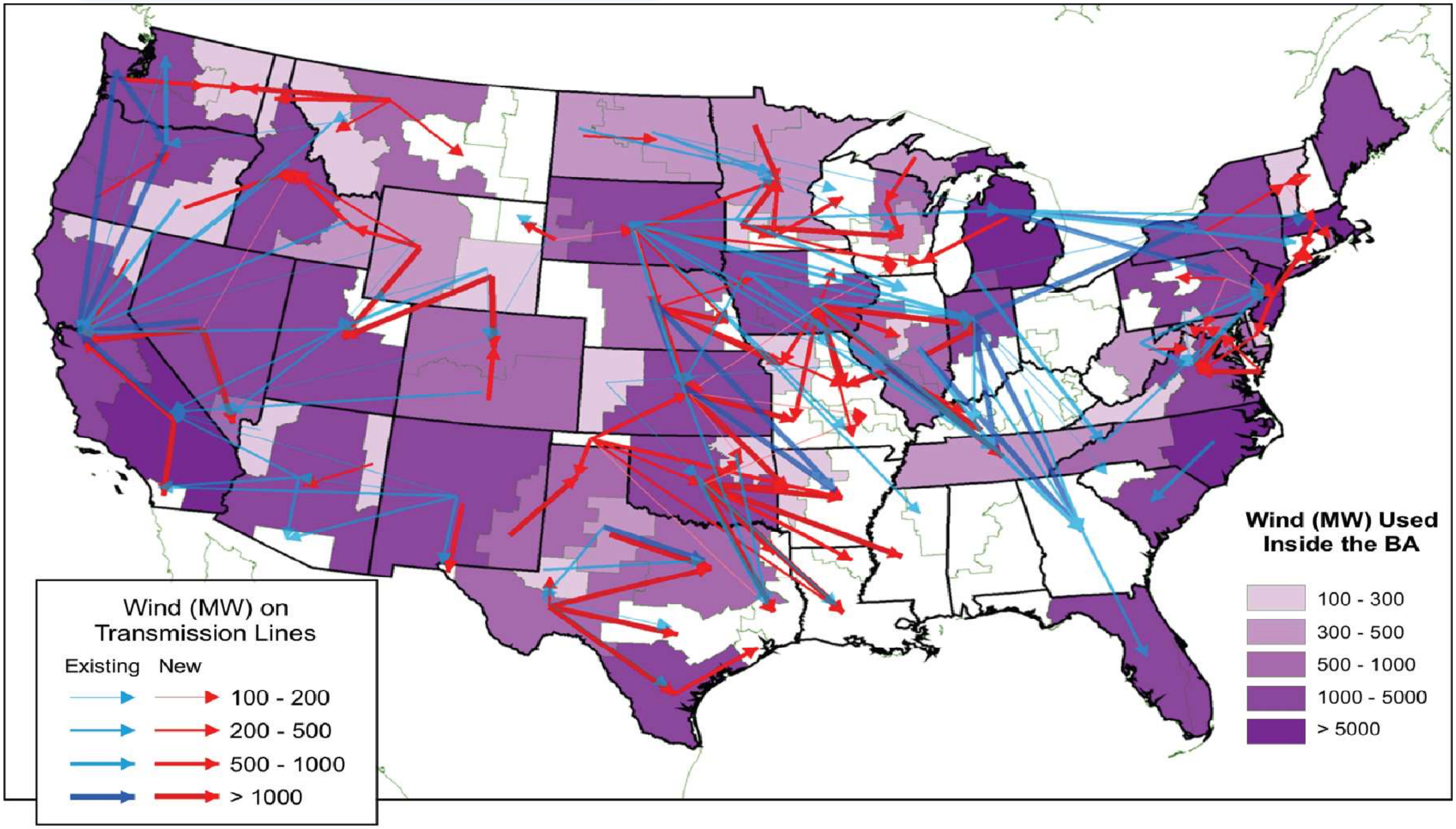


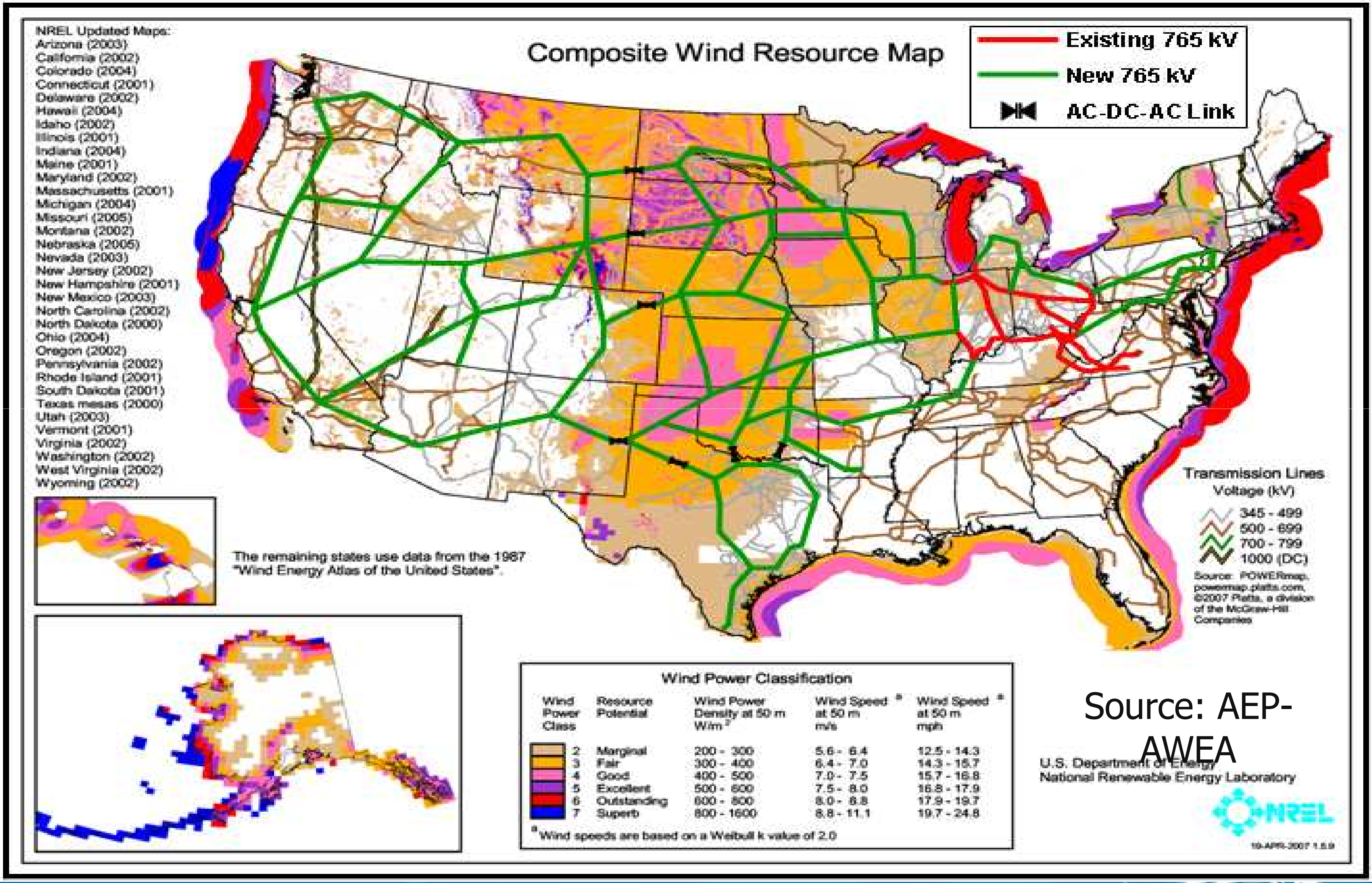
20% Wind Vision



Total Between Balancing Areas Transfer >= 100 MW (all power classes, land-based and offshore) in 2030.
Wind power can be used locally within a Balancing Area (BA), represented by purple shading, or transferred out of the area on new or existing transmission lines, represented by red or blue arrows. Arrows originate and terminate at the centroid of the BA for visualization purposes; they do not represent physical locations of transmission lines.

Source: DOE 20% Report

AC Scenario

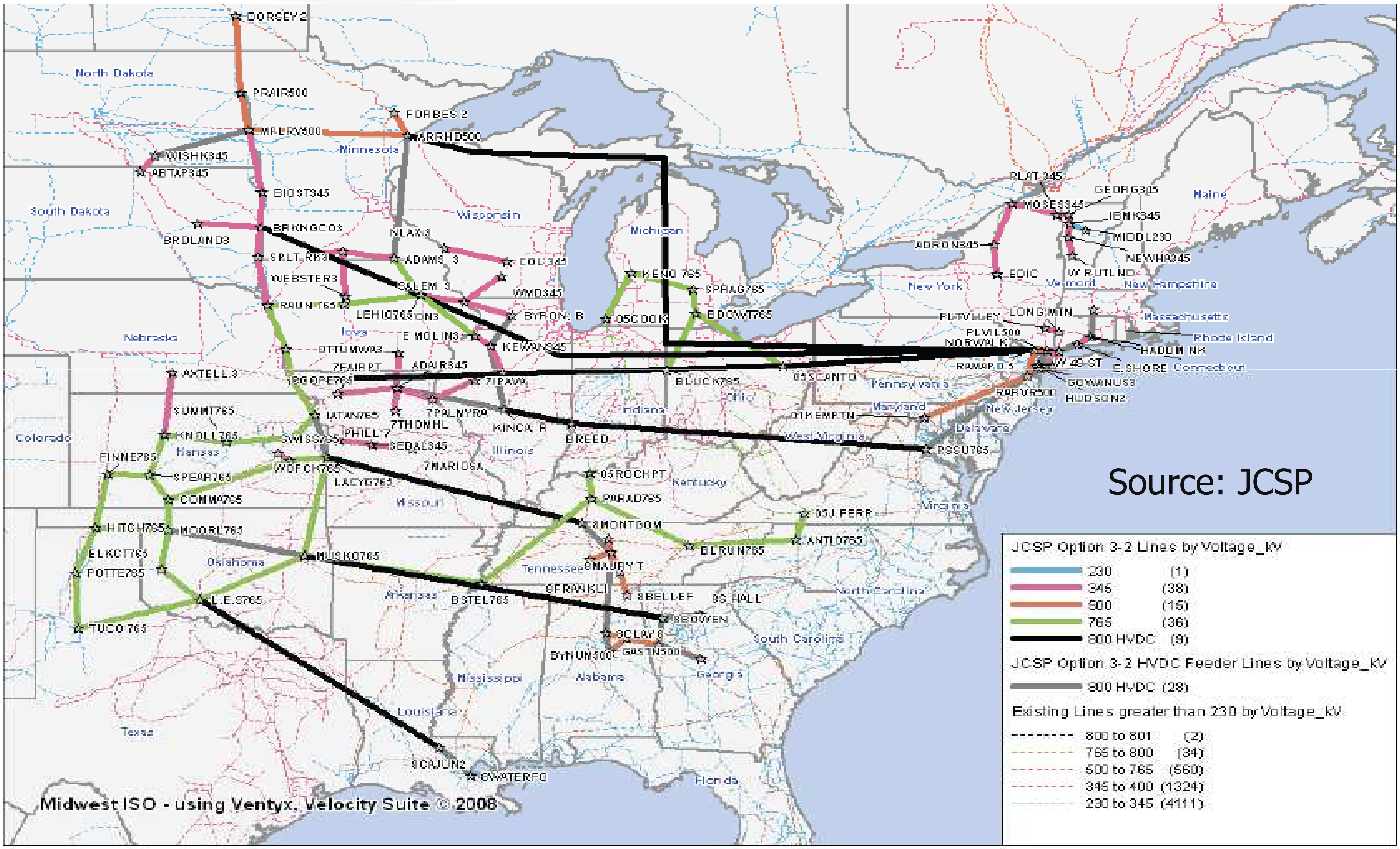


Wind Power Class	Resource Potential	Wind Power Density at 50 m W/m²	Wind Speed[a] at 50 m m/s	Wind Speed[a] at 50 m mph
2	Marginal	200 - 300	5.6 - 6.4	12.5 - 14.3
3	Fair	300 - 400	6.4 - 7.0	14.3 - 15.7
4	Good	400 - 500	7.0 - 7.5	15.7 - 16.8
5	Excellent	500 - 600	7.5 - 8.0	16.8 - 17.9
6	Outstanding	600 - 800	8.0 - 8.8	17.9 - 19.7
7	Superb	800 - 1600	8.8 - 11.1	19.7 - 24.8

[a] Wind speeds are based on a Weibull k value of 2.0

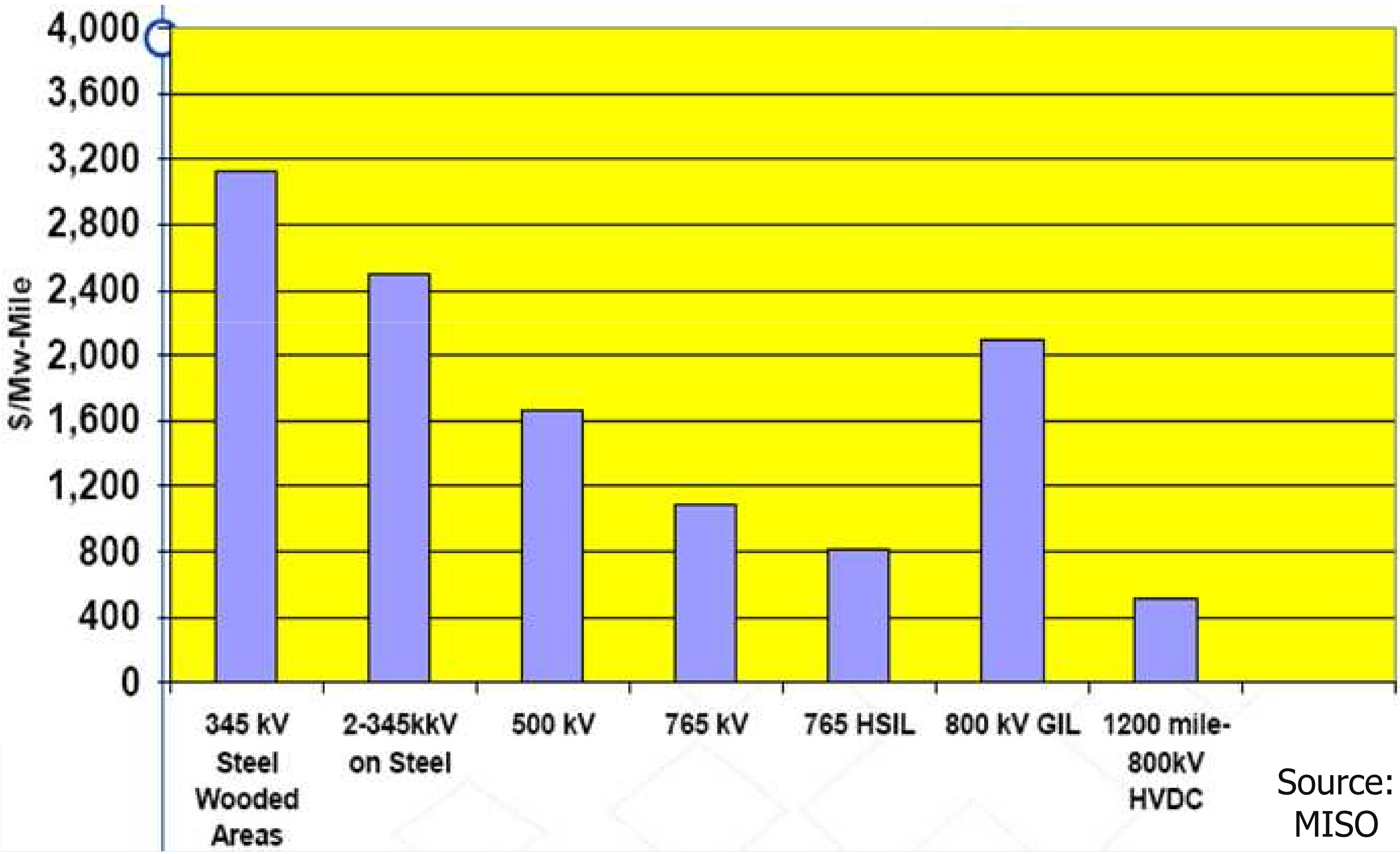
Source: AEP-AWEA

DC scenario



Source: JCSP
JCSP Option 3-2 Lines by Voltage_kV
230 (1)
345 (38)
500 (15)
765 (36)
800 HVDC (9)
JCSP Option 3-2 HVDC Feeder Lines by Voltage_kV
800 HVDC (28)
Existing Lines greater than 230 by Voltage_kV
800 to 801 (2)
765 to 800 (34)
500 to 765 (560)
345 to 400 (1324)
230 to 345 (4111)
Midwest ISO - using Ventyx, Velocity Suite © 2008
North Dakota
South Dakota
Nebraska
Colorado
Kansas
Oklahoma
Texas
Minnesota
Wisconsin
Iowa
Missouri
Arkansas
Louisiana
Mississippi
Alabama
Georgia
Florida
Tennessee
Kentucky
Illinois
Indiana
Ohio
Michigan
Pennsylvania
New York
Maryland
Delaware
New Jersey
Virginia
West Virginia
North Carolina
South Carolina
Vermont
New Hampshire
Maine
Massachusetts
Rhode Island
Connecticut

Economies of Scale for High-Capacity Transmission



Source: MISO

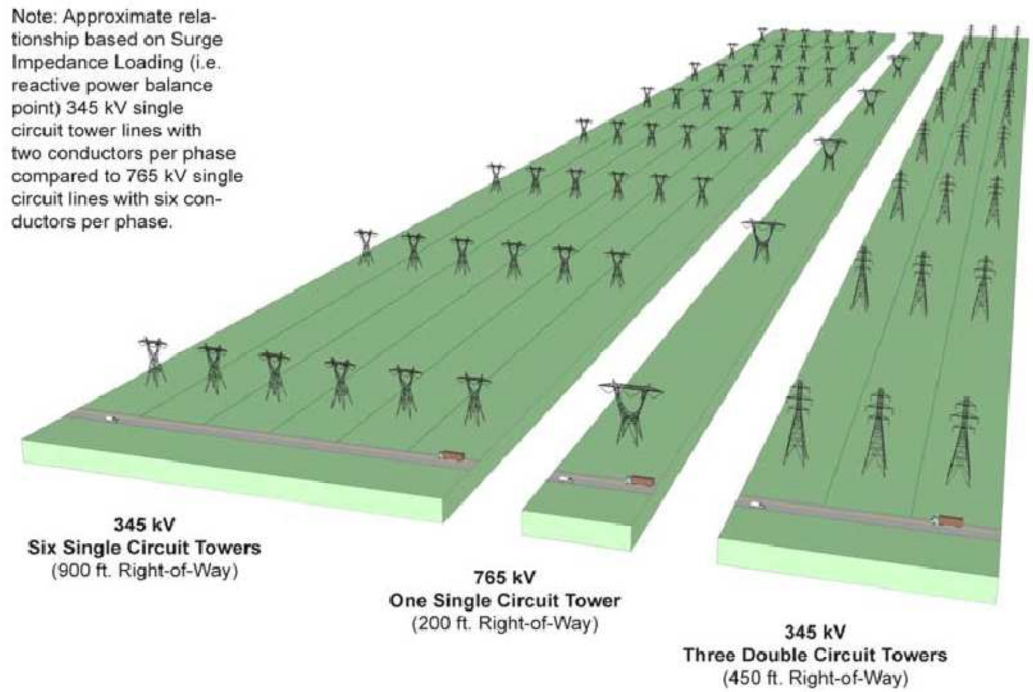
Reduced Land Use

765-kV benefits are substantial over 500-kV and 345-kV.

Description	765	500	345	345
Circuits/Tower	1	1	1	2
Conductors/Phase	6	3	2	2
SIL per Line (MW)	2400	910	400	800
Lines Required for 2400 MW Capacity	1	3	6	3
ROW per line (ft)	200	200	150	150
Total ROW (ft)	200	600	900	450
ROW utilization factor	100%	38%	22%	44%
Typical Height (ft)	132	124	110	172
*Cost/Mile ($M) for 2400 MW capacity	2.6	6.9	6.6	4.5

* Cost in 2007 $US, based on average terrain.

** SIL is a relative capacity measure, thermal capacity is over 4000 MW for 765 kV and ~ 2000 MW for 500 kV.



Source: AEP

Transmission voltage selection significantly affects performance, cost and the environment.

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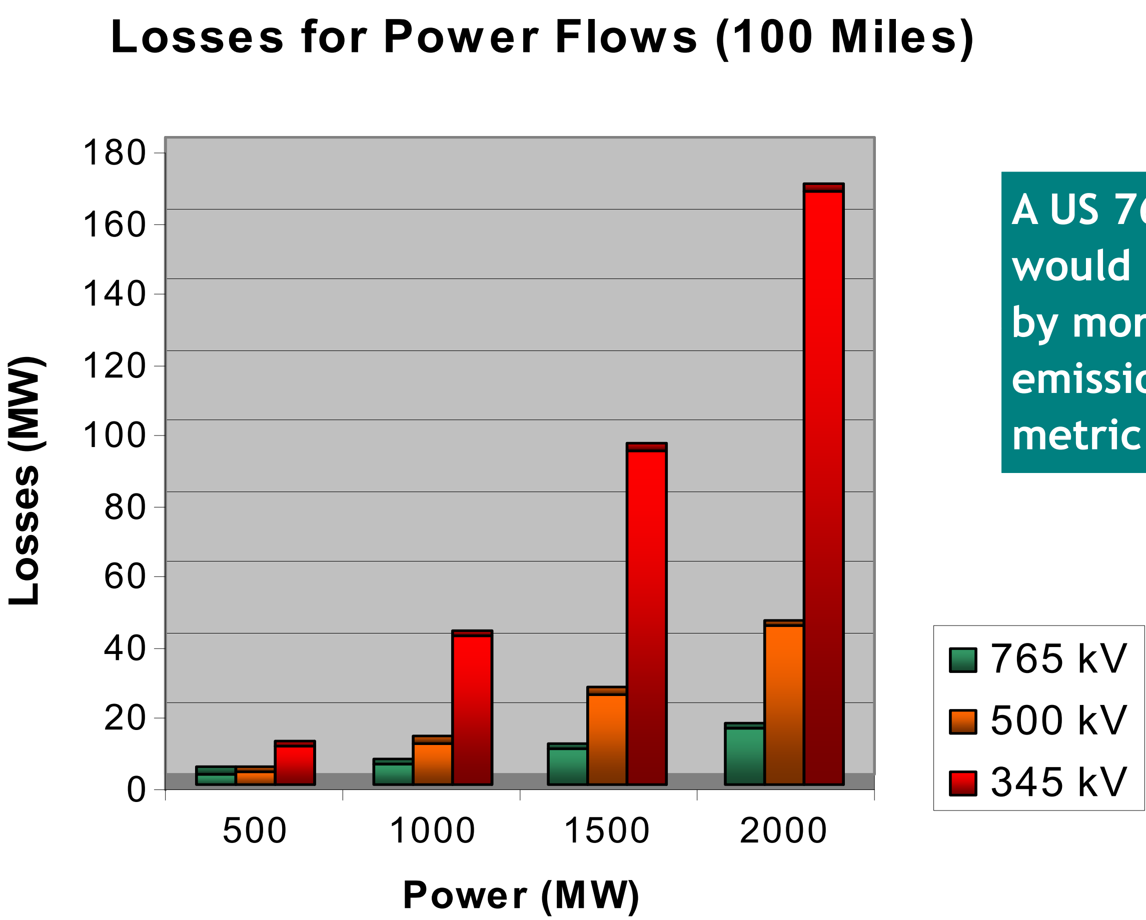
Efficiency of High Voltage Transmission

Advanced transmission enables energy savings through efficiency.



A US 765-kV transmission overlay would reduce peak load losses by more than 10 GW and CO2 emissions by some 15 million metric tons annually.

Source: AEP

The Market Failures

- Economic benefits of transmission do outweigh costs:
  - Joint Coordinated System Plan: Would pay for itself in 7 years
  - Texas study: Would pay for itself in 3 years
  - Reliability benefits
  - Fuel price volatility benefits
  - Benefits of connected renewables: environmental, economic development, energy security

- Why don't we just build the transmission?

Market Failure #1: Planning

- The Chicken and Egg Problem
  - Wind and solar projects can be built in 1-2 years, transmission lines take at least 5 years
  - Transmission developers wait for renewable developers, and vice versa
  - Wind and solar projects are also more dispersed and tend to be smaller than conventional generation

- Solution: Pro-active planning

Solution #1:
Pro-active Planning

- Pro-actively plan transmission to renewable resource zones
- Plan transmission for future needs and needs of broad geographic regions to capture economies of scale

- Success stories
  - Texas Competitive Renewable Energy Zone (CREZ) process
  - Colorado process
  - California RETI
  - Western Renewable Energy Zone project

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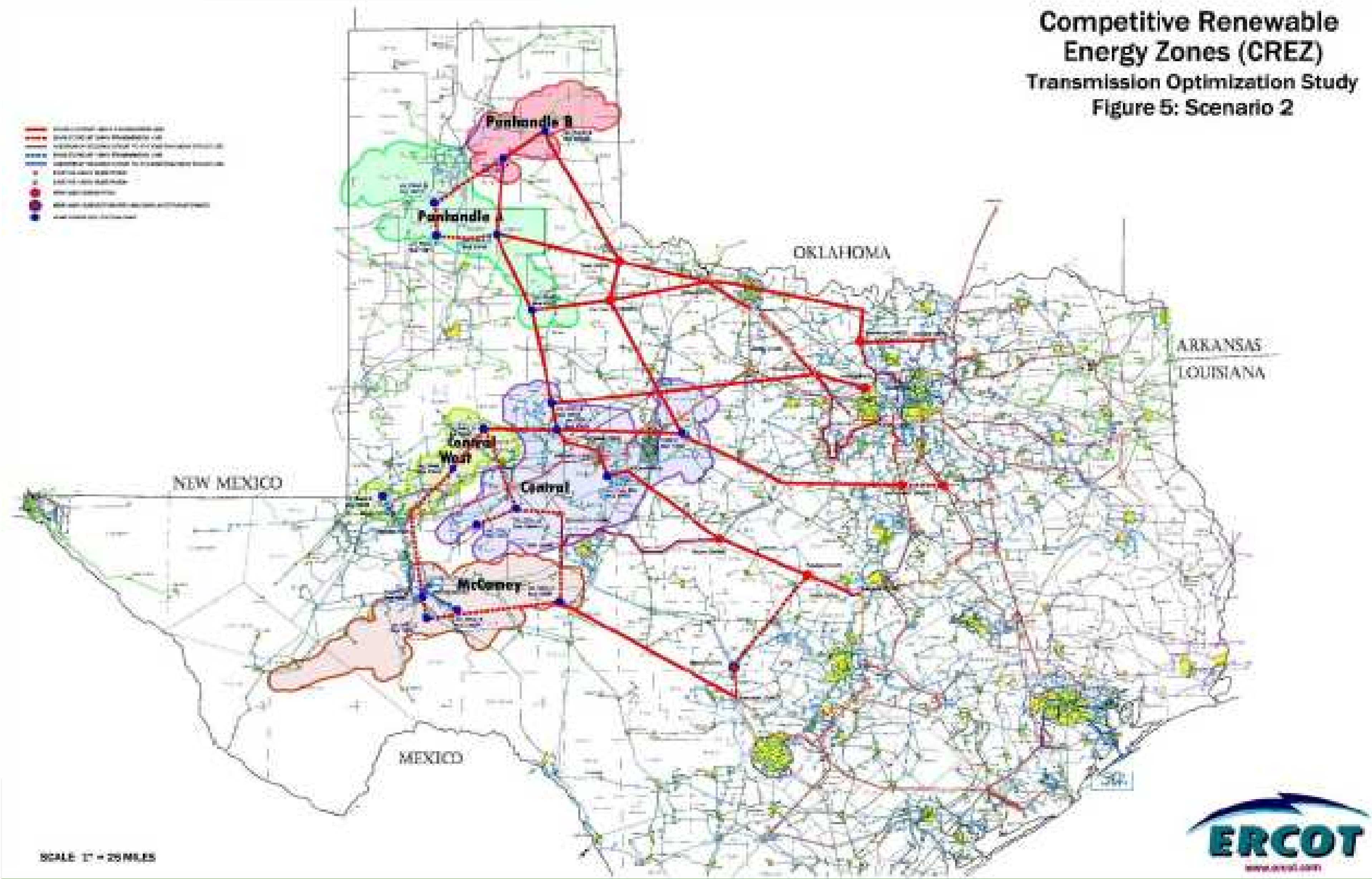
Market Failure #2: Paying

- Once you plan the transmission, you need to pay for it
- But there is a huge incentive to free-ride on others (classic public goods problem)
  - Free-rider problem for connecting to the grid
  - Free-rider problem for inter-state transmission
- Solution: Broad, regional cost allocation

Solution #2:
Broad, regional cost allocation

- Since everyone benefits from transmission, assign the costs of transmission upgrades to all users over a broad region
- Transmission costs are very small – less than 10% of your electric bill
- Consumer benefits from reduced electricity costs almost always make up the difference
- Given longevity of transmission infrastructure, impossible to precisely determine who benefits
- Success Stories:
  - Texas CREZ, Colorado, California RETI
  - Southwest Power Pool proposal

Success Story:
Texas CREZ Process



Market Failure #3: Permitting

- Once you plan and pay for transmission, you need to build it
- Not In My Backyard (NIMBY) public goods problem
- NIMBY's can hold up or block project that would benefit entire region or nation
- Siting policies need to be reformed
- Overlapping federal siting authority is major problem in the West, where various federal entities own more than half the land and each entity has its own permitting process
- An individual state can hold up or block a project that would benefit an entire region
- Solution: More coordinated, streamlined siting authority

Transmission Policy

- Policies for new transmission construction
  - Planning (pro-active planning)
  - Paying (broad regional cost allocation)
  - Permitting (streamlined siting)
- Improve grid operations
  - Coordinated regional grid operations
    - Balancing area consolidation/cooperation
    - Faster generator scheduling and dispatch
    - More and better use of wind forecasting
- AWEA-SEIA white paper at www.awea.org/

Transmission Proposals

- U.S. Senate proposals
  - Contain some aspects of planning, cost allocation, and permitting
- U.S. House Waxman-Markey bill
  - Only addresses planning

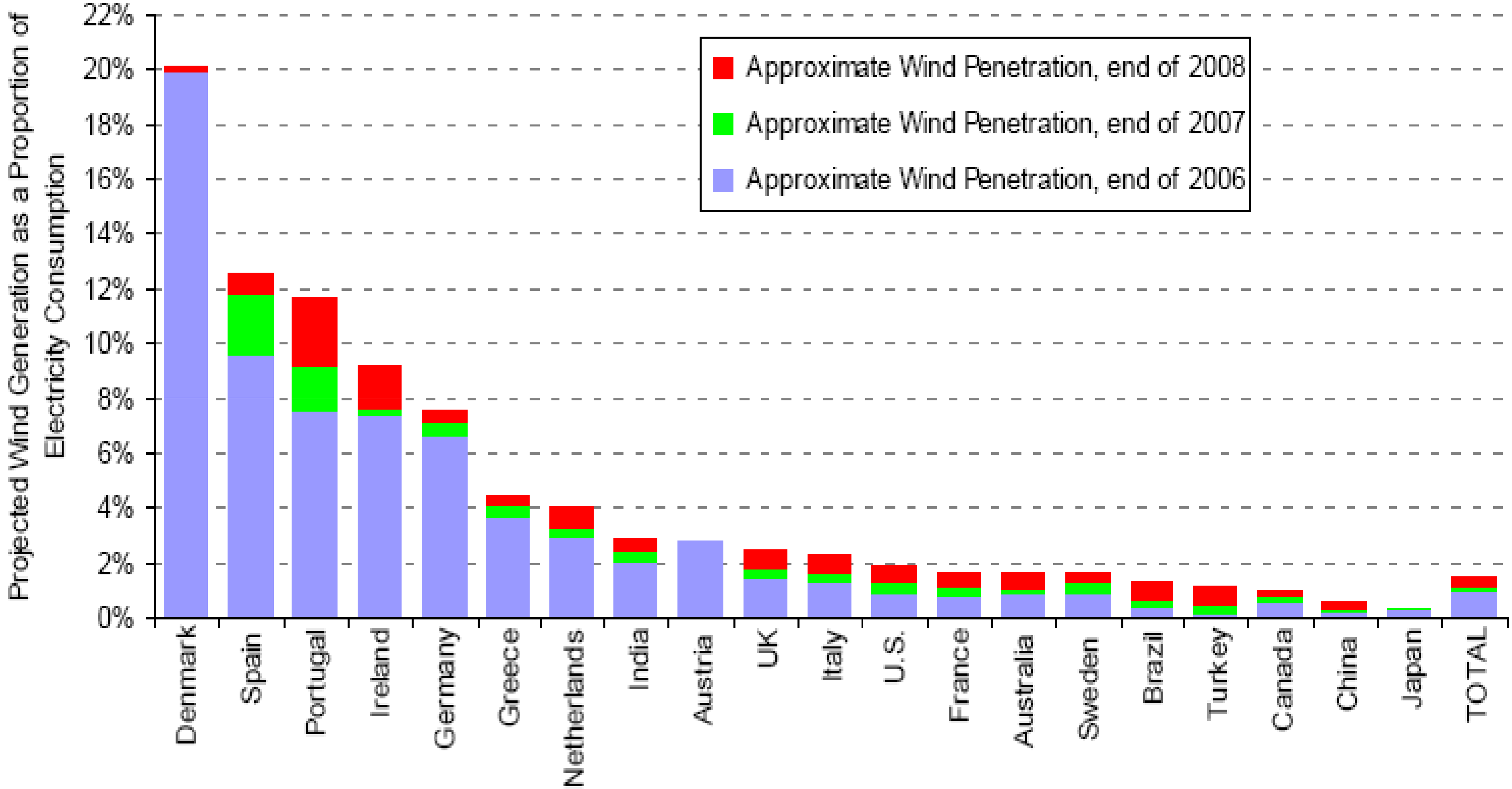
Wind Integration

Current Wind Penetration in the U.S., by state

Minnesota	7.5%	Wyoming	2.0%
Iowa	7.1%	South Dakota	1.9%
Colorado	5.9%	Montana	1.9%
North Dakota	4.9%	Idaho	1.7%
New Mexico	4.4%	New York	0.9%
Oregon	4.3%	Maine	0.8%
Kansas	3.8%	Nebraska	0.7%
Texas	3.5%	Wisconsin	0.7%
Washington	3.3%	West Virginia	0.4%
Oklahoma	3.0%	Pennsylvania	0.3%
California	2.7%	Missouri	0.2%
Hawaii	2.1%	Indiana	0.2%

Source: AWEA data, EIA forms 906 and 920, 2008 data

Current European Wind Energy Penetration



Source: Berkeley Lab estimates based on data from BTM Consult and elsewhere

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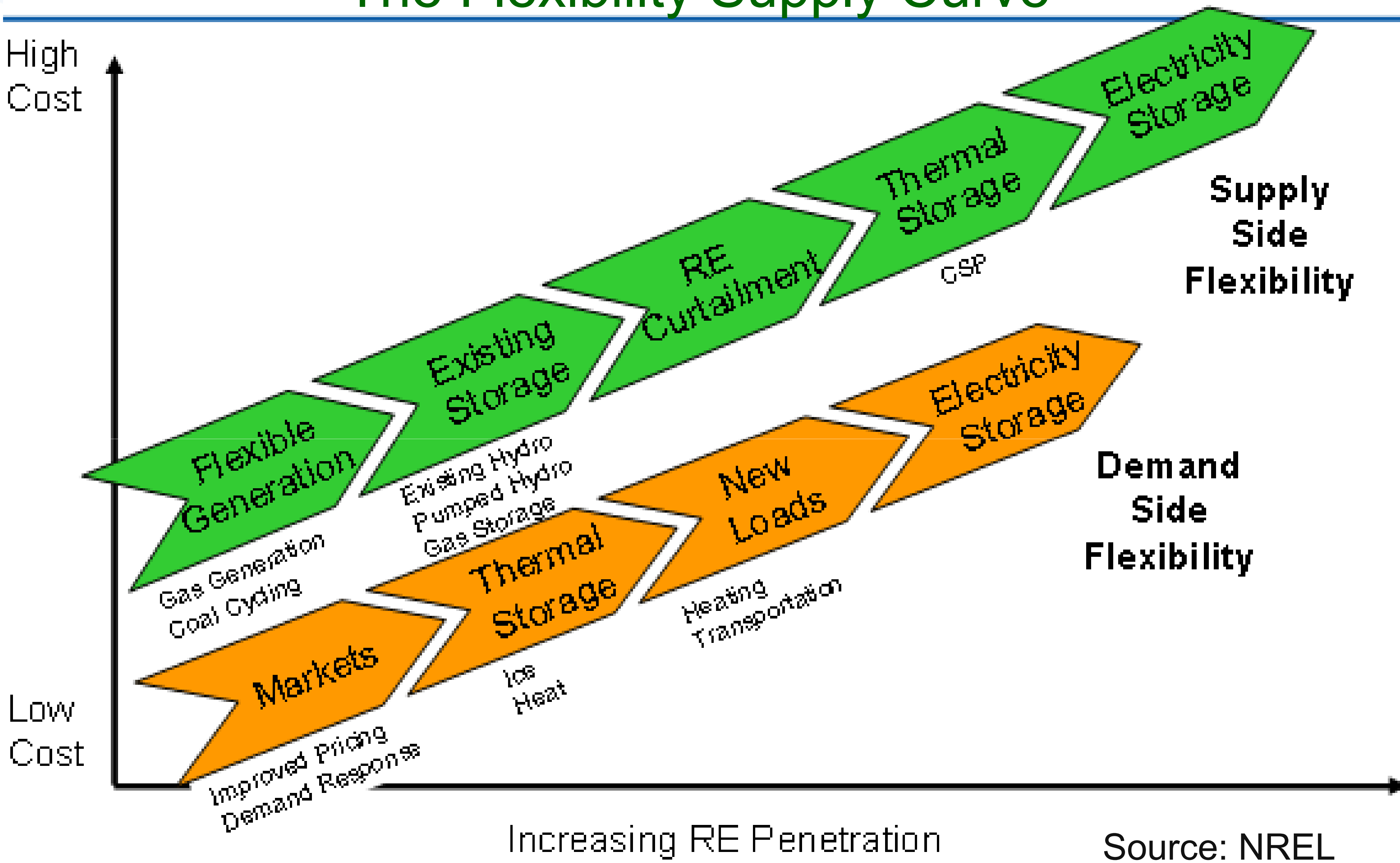
Power System Operations: Background

- Supply and demand of electricity must match at all times
- Grid operators accomplish this by increasing and decreasing the output of flexible generators, like hydroelectric and natural gas power plants
- Electricity demand is highly variable; forecasts are used, but there is still variability and uncertainty
- Electricity supply is also variable and uncertain
- As a result, grid operators hold generation in reserve:
  - Regulation reserves
  - Load-following reserves
  - Contingency reserves
- Reserves can be spinning or non-spinning

The Flexibility Supply Curve



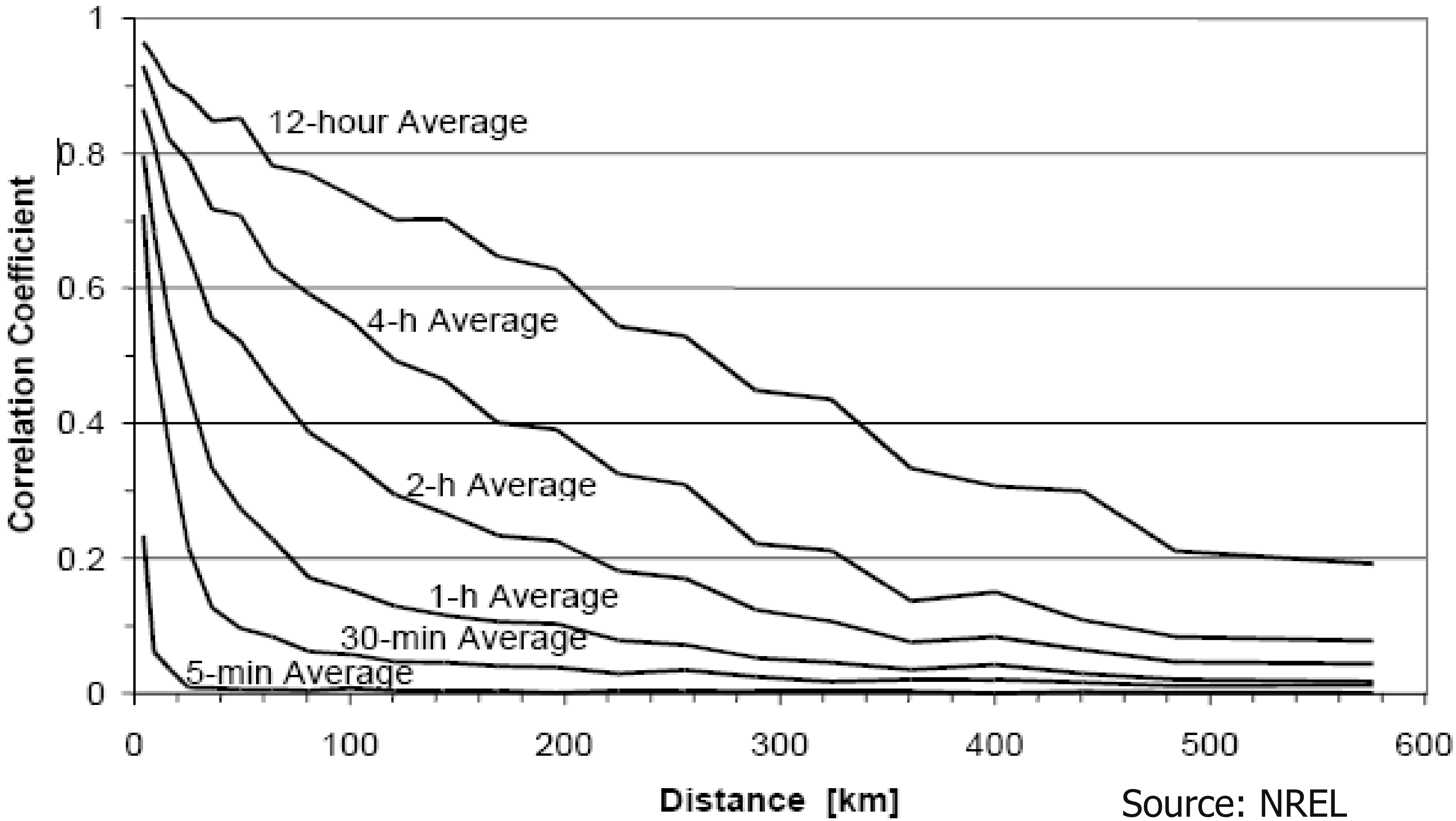
Source: NREL

Lessons Learned about Wind Integration

- Wind forecasting can significantly reduce integration costs by reducing uncertainty
- Geographically diverse wind resources tend to be less variable
- Wind resources spread over larger areas are less variable – one of the reasons why transmission is important
- Diverse wind has very little variability on the minute-to-minute time scale
- Wind is easier to integrate on more flexible power systems
- Market/system operation reforms can significantly reduce wind integration costs
- A robust transmission grid can significantly reduce integration costs
- Integrating wind is a cost issue, not a reliability issue (thinking about “limits” or renewable thresholds is inaccurate)
- Storage is not needed

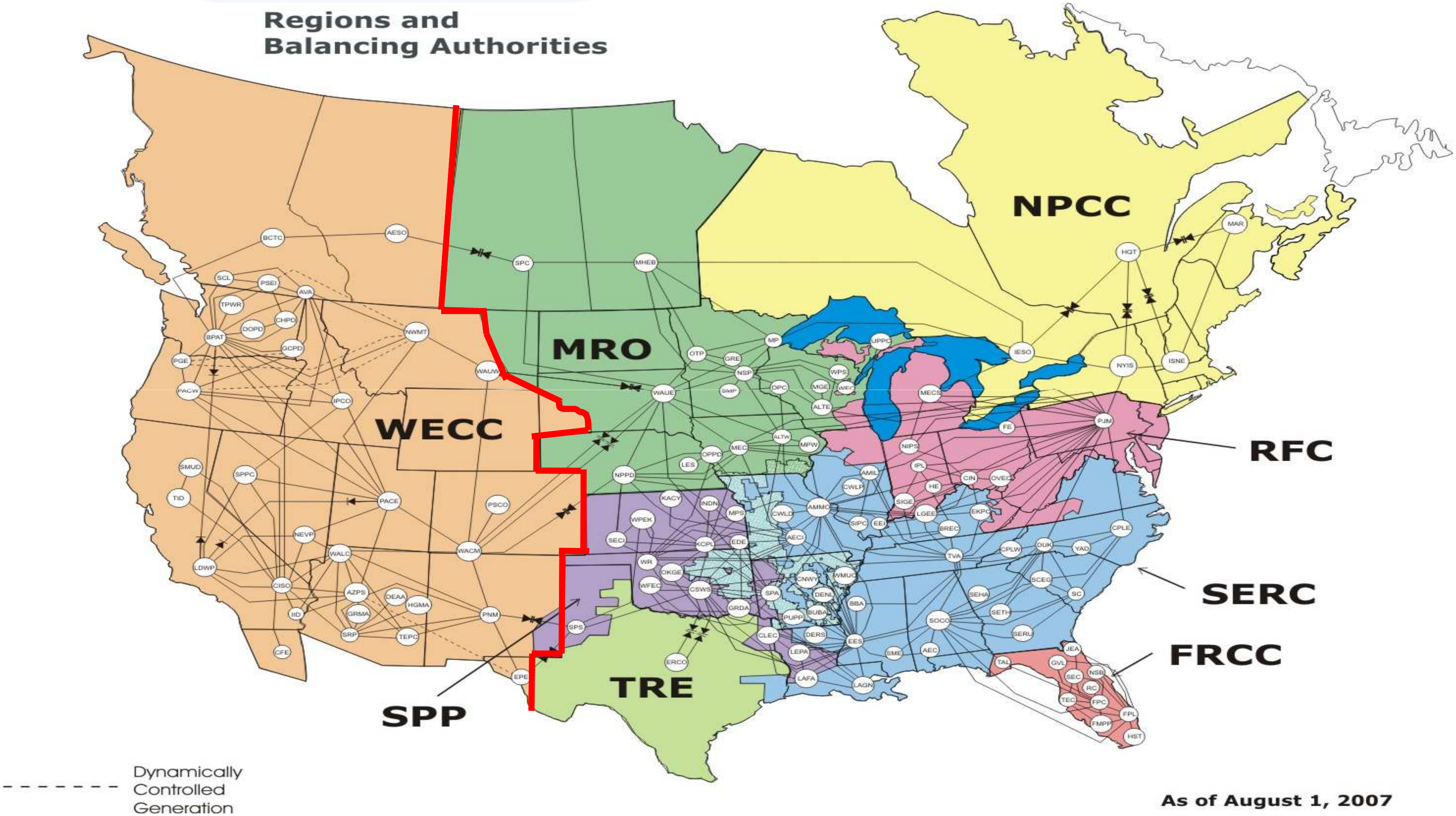
The Distance Element of Wind's Variability

Correlation in plant output as a function of time and distance



Source: NREL

Grid Balkanization Impairs Wind Integration



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The Time Element of Wind’s Variability

Study	Wind Penetration	1 minute	5 minute	1 hour
Texas 2008[1]	15,000 MW	6.5 MW	30 MW	328 MW
California Energy Commission 2007[2]	2,100 MW, +330MW solar	0.1 MW	0.3 MW	15 MW
	7,500 MW, +1,900 MW solar	1.6 MW	7 MW	48 MW
	12,500 MW, +2,600 MW solar	3.3 MW	14.2 MW	129 MW
New York 2005[3]	3,300 MW	- -	1.8 MW	52 MW

[1] http://www.uwig.org/Wind_Generation_Impact_on_Ancillary_Services_-_GE_Study.zip

[2] http://www.uwig.org/CEC-500-[illegible]-APB.pdf

[3] http://www.uwig.org/nyserdaphase2appendices.pdf

Wind Integration Costs

Date	Study	Wind Capacity Penetration (%)	Regulation Cost ($/MWh)	Load Following Cost ($/MWh)	Unit Commitment Cost ($/MWh)	Gas Supply Cost ($/MWh)	Total Operating Cost Impact ($/MWh)
May ‘03	Xcel-UWIG	3.5	0	0.41	1.44	na	1.85
Sep ‘04	Xcel-MNDOC	15	0.23	na	4.37	na	4.60
June ‘06	CA RPS	4	0.45*	trace	na	na	0.45
Feb ‘07	GE/Pier/CAIAP	20	0-0.69	trace	na***	na	0-0.69***
June ‘03	We Energies	4	1.12	0.09	0.69	na	1.90
June ‘03	We Energies	29	1.02	0.15	1.75	na	2.92
2005	PacifiCorp	20	0	1.6	3.0	na	4.60
April ‘06	Xcel-PSCo	10	0.20	na	2.26	1.26	3.72
April ‘06	Xcel-PSCo	15	0.20	na	3.32	1.45	4.97
Dec ’08	Xcel-PSCo	20			3.95	1.18	5.13-6.30****
Dec ‘06	MN 20%	31**					4.41**
Jul ‘07	APS	14.8	0.37	2.65	1.06	na	4.08

Source: NREL

Questions?

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